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Acoustic Propagation Through Surface Ship Wakes

S. Stanic,[1] T. Ruppel,[1] and R. Goodman[2]
[1]*Acoustics Division*
[2]*University of Southern Mississippi*

Introduction: A ship's wake is a mixture of bubbles and turbulent seawater generated by a ship's hull and its cavitating propellers. These bubble clouds are a common feature of all ship wakes, and the entrapped air bubbles are responsible for the lingering acoustic signatures of a ship's wake. It is well known that bubbles, even in small amounts, cause considerable frequency-dependent changes in the speed of sound and absorption. These bubble-cloud characteristics are driven by the type of ship, its speed, and local oceanographic conditions.

As the wake ages, it goes from a violent breakup and mixing of bubbles due to turbulence to one where, as the turbulence decays, the bubbles begin to rise toward the surface due to their buoyancy and the changes in the buoyancy of the water mass. It is clear that since bubbles of different sizes rise at different rates, as the wake ages, the horizontal and vertical distributions of bubble densities result in changes to both sound-speed profiles and absorption within the wake. These frequency-dependent sound-speed profiles have dramatic effects on propagating acoustic signals.

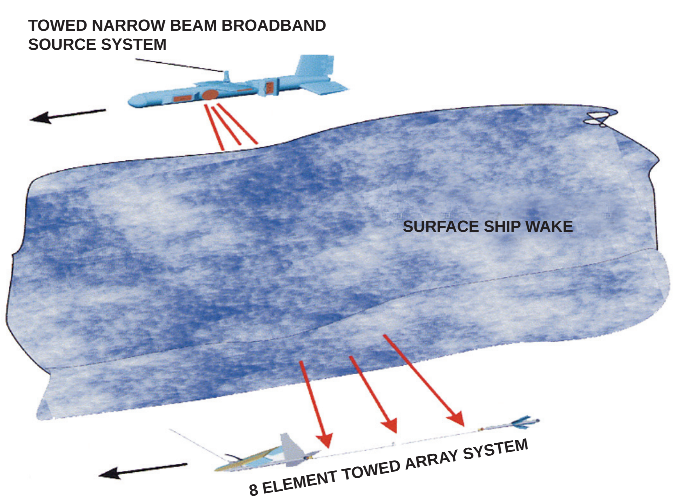
Field Measurements: A series of across-the-wake acoustic absorption measurements were taken in the summer of 2004. A 10-meter-long, 8-element receiving array and broadband source were towed by separate ships on either side of a wake generated by a small Naval vessel traveling at 15 kt. The vessel, a YDT, was provided by NAVDIVESALVTRACEN Panama City, Florida. The YDT is 131 ft long, 26.6 ft wide, has a draft of 4.95 ft, and displaces 173 light tons.

Figure 10 shows the source-receiver measurement configuration and the receiving array tow ship. The wake width is approximately 10 m and the distance between the measurement systems is 150 m. This range is monitored by a laser system and recorded. The measurement systems are towed at a speed of 4.5 kt. The signal repetition rate of 1 s gave an across-the-wake absorption measurement every 7.5 m.

Figure 11 shows the average acoustic absorption across the wake for a number of frequencies as a function of distance from the time the measurement sequence began. The maximum absorption clearly occurs at a range of about 500 m after the start of the measurement sequence. This was the most intense part of the wake that occurred about 20 m behind the YDT. The average across-the-wake absorption levels returned to the nonbubble background levels at a distance of about 2 km. In these measurements, the maximum absorption occurs at a frequency of 100 kHz, suggesting a large number of 30-μm-diameter bubbles in that part of the wake.

From the absorption measurements, the void fractions and the sound velocities were calculated for a 10-m deep wake. Figure 12(a) shows the frequency-dependent sound velocity profiles at 5, 20, 60, and 120 kHz that were derived from the absorption measurements and a simple model for the vertical dependence of the bubble densities.

Figure 12(b) shows the ray plots for a source located at a depth of 10 m, which is near the lower portion of the wake. These ray plots clearly show the



(a)

(b)

FIGURE 10
(a) Measurement configuration and (b) generated wake and array tow ship.

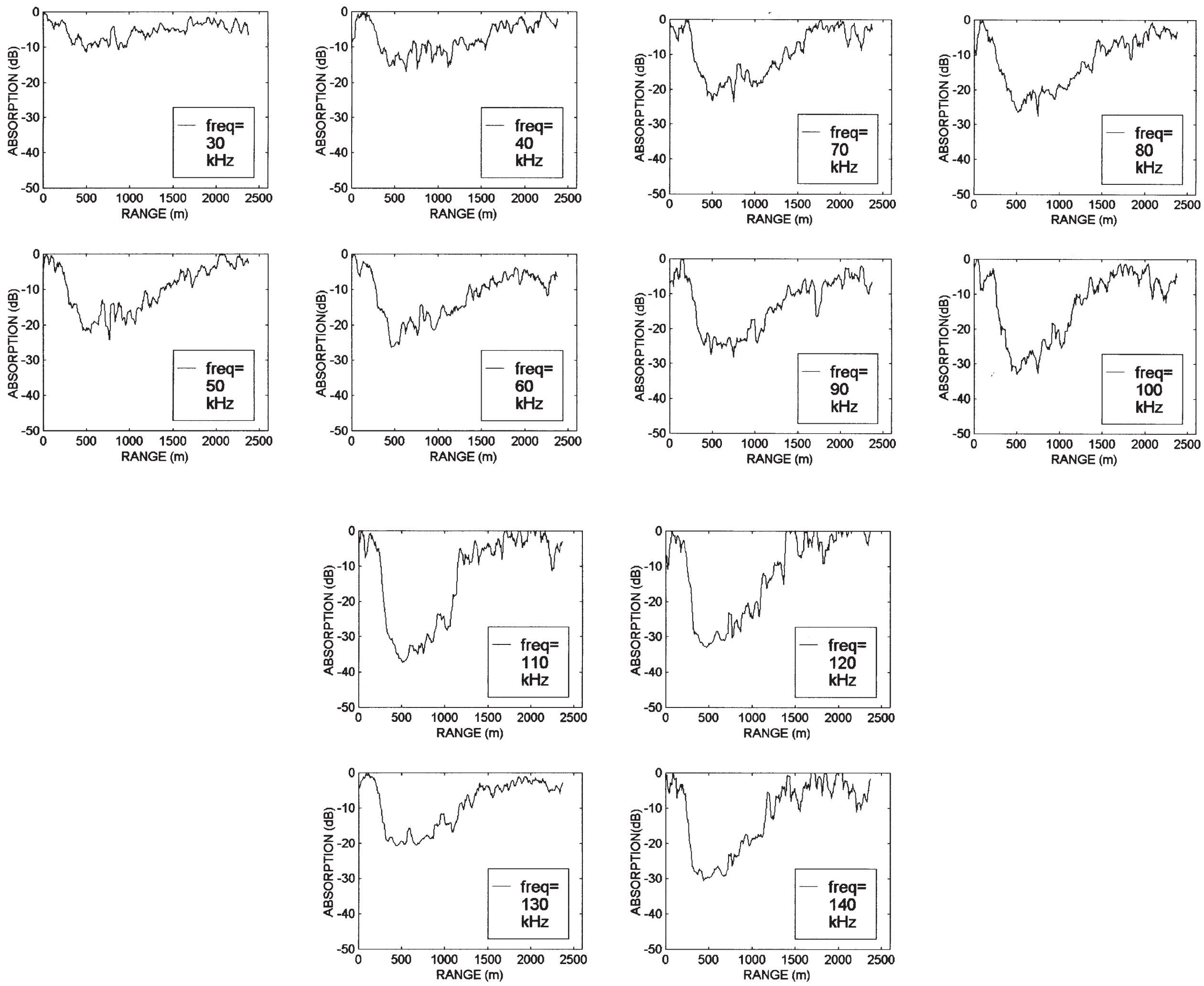
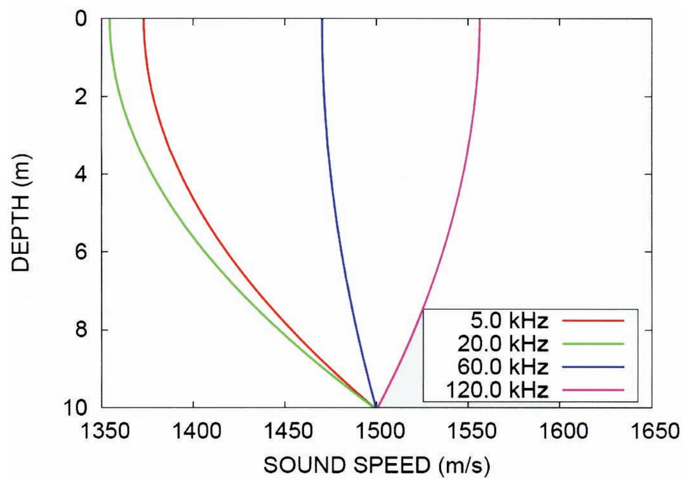
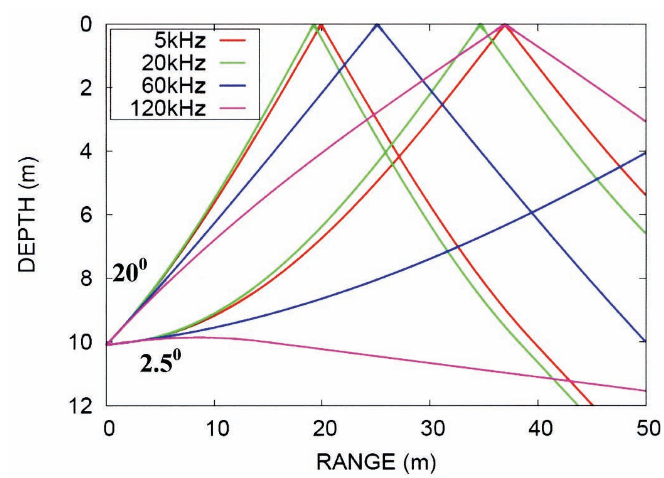


FIGURE 11
Average signal absorption as a function of range and frequency.



(a)



(b)

FIGURE 12
(a) Calculated frequency-dependent sound velocity profiles. (b) Ray paths corresponding to the different sound velocity profiles at launch angles of 2.5° and 20°.

dispersive effects of the sound velocity profiles. For launch angles of 2.5° and 20°, and at frequencies of 5, 20, and 60 kHz, the acoustic conditions are clearly upward-refracting, while at a frequency of 120 kHz, the conditions are downward-refracting.

Summary and Impact: NRL has developed a method for providing valuable data and performance estimates for target detections in and below a surface ship wake. The varying vertical and horizontal distribution of bubbles and the corresponding fluctuating absorptions provide insight into target detections in and below a surface ship wake.

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